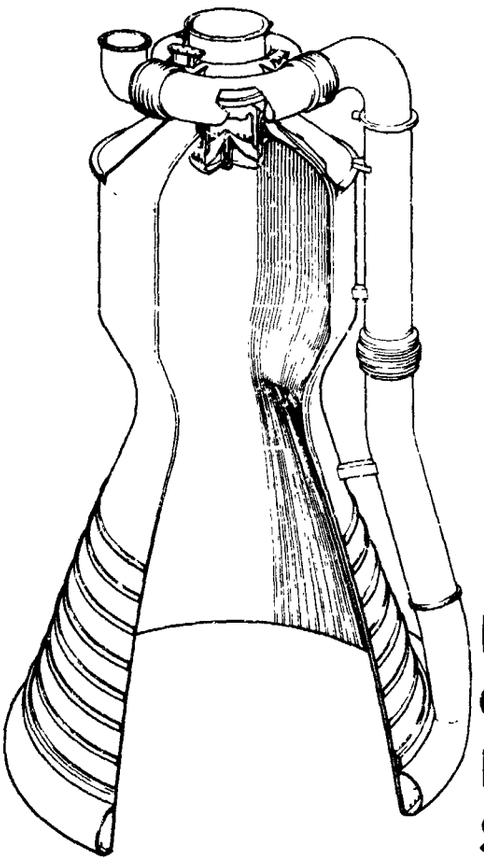
15295

SE-019-015-2H



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FEASIBILITY STUDY OF A PRESSURE-FED ENGINE FOR A WATER RECOVERABLE SPACE SHUTTLE BOOSTER

MASS PROPERTIES REPORT

CR-123604

(NASA-CR-123604) FEASIBILITY STUDY OF A PRESSURE-FED ENGINE FOR A WATER RECOVERABLE SPACE SHUTTLE BOOSTER E. Gerstl (TRW Systems Group) [1972] 28 p CSCL 21H

N72-22781

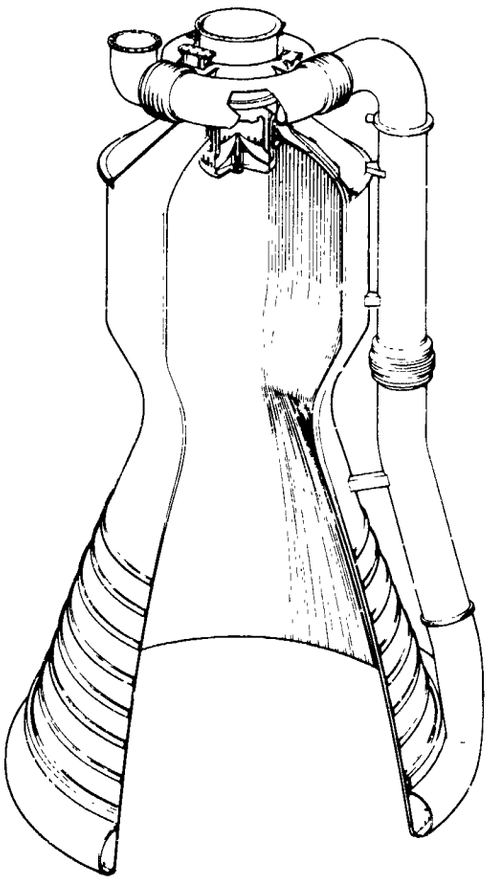
Unclas
G3/28 15295

PREPARED FOR
GEORGE C. MARSHALL SPACE FLIGHT CENTER
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
HUNTSVILLE, ALABAMA

TRW
SYSTEMS GROUP
ONE SPACE PARK • REDONDO BEACH • CALIFORNIA

CAT. 28

SE-019-015-2H



FEASIBILITY STUDY OF A PRESSURE-FED ENGINE FOR A WATER RECOVERABLE SPACE SHUTTLE BOOSTER

MASS PROPERTIES REPORT

DRD SE-03

PREPARED FOR
GEORGE C. MARSHALL SPACE FLIGHT CENTER
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
HUNTSVILLE, ALABAMA

TRW
SYSTEMS GROUP
ONE SPACE PARK • REDONDO BEACH • CALIFORNIA

SE-019-015-2H

TRW SYSTEMS

STATUS MASS PROPERTIES DATA REPORT

FOR THE PRESSURE FED ENGINE STUDY

Prepared For

National Aeronautics & Space Administration

George C. Marshall Space Flight Center

Huntsville, Alabama 35812

Under Contract
NAS8-28218

Prepared By: _____
E. Gerstl

Approved By: _____
M. N. Sherwood, Head
Mass Properties and
Operations Data Section

Approved By: _____
Dr. Harland Burge
Program Manager
Pressure Fed Engine Study

TABLE OF CONTENTS

INTRODUCTION

This report has been prepared in partial fulfillment of contract NAS 8-28218 entitled, "Feasibility Study of a Pressure-Fed Engine for a Water Recoverable Space Shuttle Booster." Included in this report are the detailed mass properties for a gimbaled, fixed thrust regeneratively cooled engine having a coaxial pintle injector; the selected engine configuration for this application. Tabulated below are the baseline design parameters for this engine.

Summary of Baseline Engine Design Parameters

Engine Cooling Technique	Fully Regenerative
Thrust Level	1,200,000 lbs
Chamber Pressure	250 psia
Propellant Combination	LOX/RP-1
Mixture Ratio	2.4:1
Nozzle Expansion Ratio	5:1
Sea Level Specific Impulse (Nominal)	227.3
Vacuum Specific Impulse (Nominal)	276.0
TVC System	Gimbal
Mission Burn Time	150 Seconds
Life	50 Missions

Since the initial trade studies documented the attractiveness of several other engine configurations i.e., a hinge nozzle using a Techroll seal, a gimbaled duct cooled engine and a regeneratively cooled engine using liquid injection thrust vector control (LITVC), mass properties are also summarized for these configurations. Detailed engine analysis and design trade studies leading to the selection of a regeneratively cooled gimbaled engine and pertaining to the selection of the baseline design configuration may be found in the Final Report. (NASA-MSFC Control Number SE-019-011-2H-B).

REVIEW FOR MANAGEMENT

This document provides the Mass Properties Report prepared by the TRW Systems Group for the feasibility study of a pressure-fed engine for a water recoverable space shuttle booster.

The Mass Properties effort at TRW Systems Group, Redondo Beach, California, is being accomplished in compliance with Contract NAS 8-28218.

All Mass Properties data are prepared in accordance with MIL-M-38310A (USAF), "Mass Properties Control Requirements for Missiles and Space Vehicles".

This report provides the status of the 1200 K gimbaled regenerative engine system with $\varepsilon = 5$. Other system weights are shown in the Review for Management for comparison only.

The TRW regenerative cooled chamber design emphasizes the fixed thrust coaxial injecter assembly in the center of the engine. The center feed LO_2 ducting is nestled within a four bearing gimbal ring. The gimbal bellows for the LO_2 feed are retained within the gimbal enclosure. The fuel line feeds in axially and across the head end with two bellows to allow for the gimbaling articulation. The fuel then feeds axially to a tapered Torus manifold at the exit of the engine.

SUMMARY OF MASS PROPERTIES FOR 1200 K REGENERATIVE ENGINE--GIMBALED, $\varepsilon = 5$

	WT. LBS.	$\bar{X}$ IN.	$\bar{Y}$ IN.	$\bar{Z}$ IN.	Ix SL-FT^2	Iy SL-FT^2	Iz SL-FT^2
Engine Dry - M.I. About C.G.	11467	72.05	103.85	97.20	5005	15915	16012
Engine Wet - M.I. About C.G.	14956	85.61	107.80	94.72	7770	26508	26747
Engine Dry - M.I. About Gimbal Plane	11467	72.05	103.85	97.20	5076	28781	28895
Engine Wet - M.I. About Gimbal Plane	14956	85.61	107.80	94.72	8057	50255	50600

SUMMARY OF MASS PROPERTIES FOR 1200 K REGENERATIVE CHAMBER WITH ABLATIVE TECHROLL® NOZZLE--GIMBALED, ε = 5

	WT. LBS.	$\bar{X}$ IN.	$\bar{Y}$ IN.	$\bar{Z}$ IN.	Ix SL-FT^2	Iy SL-FT^2	Iz SL-FT^2
Engine Dry - M.I. About C.G.	11979	111.61	103.43	97.03	6533	16867	16915
Engine Wet - M.I. About C.G.	14268	107.60	105.58	94.81	7506	18770	18814
Engine Wet - Plus Actuators & Servos M.I. About C.G.	14730	109.06	105.40	94.97	7756	19102	19147
Engine Dry - M.I. About Structural Interface	11979	111.61	103.43	97.03	6586	44918	44973
Engine Wet - M.I. About Structural Interface	14268	107.60	105.58	94.81	7685	49715	49771
Engine Wet - Plus Actuators & Servos M.I. About Structural Interface	14730	109.06	105.40	94.97	7929	51979	52037
Engine - M.I. of Gimbaled Mass About Gimbal Plane					3075	2480	2480

GIMBALED REGENERATIVE ENGINE SYSTEM WEIGHT VS. THRUST (GIMBAL ACTUATORS AND APU SYSTEM NOT INCLUDED)

	600K	900K	1200K	1400K
Dry Weight, Gimbaled	4424	7678	11467	14298
Residual Fuel	1120	2050	3152	3980
Residual Oxidizer	120	219	337	425
Wet Weight, Gimbaled	5664	9947	14956	18703
Dry Weight, LITVC	4460	7790	11561	14300
Residual Fuel	1177	1870	2859	3580
Residual Oxidizer	723	1140	1755	2220
Wet Weight, LITVC	6360	10800	16175	20100

1200 K REGENERATIVE ENGINE - GIMBALED

	FUNCT. CODE	CURRENT WEIGHT POUNDS	CENTER OF GRAVITY INCHES			MOMENT OF INERTIA SLUG-FEET^2			PRODUCTS OF INERTIA SLUG-FEET^2 *		
			LONG. X	LAT. Y	VERT. Z	ROLL I_X	PITCH I_Y	YAW I_Z	P_{XY} P_I	P_{XZ} P_I	P_{YZ} P_I
Valves		980	15.71	126.70	78.70	10	20	20			
Injector		660	20.50	100.00	100.00	7	30	30			
Fuel Manifold & Duct		676	195.00	123.00	85.00	740	1900	1900			
Chamber Assembly		5675	104.95	100.00	100.00	3561	6206	6206			
Gimbal Assembly		1676	3.20	100.00	100.00	107	92	92			
Gimbal Support Structure		1400	26.20	100.00	100.00	100	85	85			
Electrical (J-Box)		20	20.00	150.00	100.00	- -	- -	- -			
Integration Hardware		380	72.04	103.85	97.20	166	527	531			
Engine - Dry - M.I. About C.G.		11467	72.05	103.85	97.20	5005	15915	16012			
Residual Fuel		3152	141.90	123.02	85.11	2480	7564	7584			
Residual Oxidizer		337	20.50	100.00	100.00	4	30	30			
Engine - Wet - M.I. About C.G.		14956	85.61	107.80	94.72	7770	26508	26747			
Engine - Dry - M.I. About Gimbal Plane		11467	72.05	103.85	97.20	5076	28781	28895			
Engine - Wet - M.I. About Gimbal Plane		14956	85.61	107.80	94.72	8057	50255	50600			

* Product Assumed to be 0

ALTERNATE - 1200 K REGENERATIVE CHAMBER WITH ABLATIVE TECHROLL® NOZZLE - GIMBALED

	FUNCT. CODE	CURRENT WEIGHT POUNDS	CENTER OF GRAVITY INCHES			MOMENT OF INERTIA SLUG-FEET^2			PRODUCTS OF INERTIA SLUG-FEET^2 *		
			LONG. X	LAT. Y	VERT. Z	ROLL I_X	PITCH I_Y	YAW I_Z	P_{XY} P_I	P_{XZ} P_I	P_{YZ} P_I
Valves		980	15.71	126.70	78.70	10	20	20			
Injector		660	20.50	100.00	100.00	7	30	30			
Fuel Manifold & Duct		421	103.36	132.20	67.79	98	267	267			
Chamber Assembly		4842	79.24	100.00	100.00	2660	1859	1859			
Ablative Nozzle		3636	211.85	100.00	100.00	2967	917	917			
Fixed Engine Support Struct.		800	32.06	100.00	100.00	299	178	178			
Nozzle Seal		240	168.00	100.00	100.00	108	54	54			
Int. Hardware		400	111.61	103.43	97.03	222	573	575			
Engine Dry - M.I. About C.G.		11979	111.61	103.43	97.03	6533	16867	16915			
Residual Fuel		1952	98.02	119.73	80.26	766	1136	1137			
Residual Oxygen		337	20.50	100.00	100.00	4	30	30			
Engine Wet - M.I. About C.G.		14268	107.60	105.58	94.81	7506	18770	18814			
Actuator (4)		300	154.00	100.00	100.00	162	81	81			
APU Servo Valves		162	154.00	100.00	100.00	81	40	40			
Engine Wet - Plus Actuators & Servos - M.I. About C.G.		14730	109.06	105.40	94.97	7756	19102	19147			

* Products Assumed to be 0

ALTERNATE - 1200 K REGENERATIVE CHAMBER WITH ABLATIVE TECHROLL® NOZZLE - GIMBALED (Cont'd)

	FUNCT. CODE	CURRENT WEIGHT POUNDS	CENTER OF GRAVITY INCHES			MOMENT OF INERTIA SLUG-FEET^2			PRODUCTS OF INERTIA SLUG-FEET^2 *		
			LONG. X	LAT. Y	VERT. Z	ROLL I_X	PITCH I_Y	YAW I_Z	P_{XY} P_I	P_{XZ} P_I	P_{YZ} P_I
Engine Dry - M.I. About Structural Interface		11979	111.61	103.43	97.03	6586	44918	44973			
Engine Wet - M.I. About Structural Interface		14268	107.60	105.58	94.81	7685	49715	49771			
Engine Wet - Plus Actuators & Servos - M.I. About Structural Interface		14730	109.06	105.40	94.97	7929	51979	52037			
Nozzle - M.I. of Gimbaled Mass About Gimbal Plane						3075	2480	2480			

* Products Assumed to be 0

MODEL REGENERATIVE ENGINE
CONFIGURATION 1200K - GIMBALED
REPORT NO.
SUBMITTAL DATE
REPORTING PERIOD

LINE	STAGE	(1)	ORIG. SPEC. WEIGHT PER (2)	APPR'D. SPEC. CHANGES (3)	REV'D. SPEC. WEIGHT AS OF (2)+(3) (4)	OVER OR UNDER WEIGHT (5)	CURRENT STATUS (4)+(5) (7)+(8)+(9) (6)	LAST STATUS REPORT DATEL (7)	CHANGES: LAST TO CURRENT STATUS GFE CHANGES (8)	CHANGES: LAST TO CURRENT STATUS CONTRACTOR CHANGES (9)	BASIS FOR CURRENT DATA % EST. (10)	BASIS FOR CURRENT DATA % CALC. (11)	BASIS FOR CURRENT DATA % ACTUAL (12)	NOTES (13)
1		Valves					(980)				100			
2		Oxidizer					535							
3		Fuel					445							
4		Injector					(660)							
5		Fuel Manifold And Duct					(676)							
6		Chamber Assembly					(5675)							
7		Head End Shell					755							
8		Head Tubes					411							
9		Combustion Chamber Shell					1759							
10		Combustion Chamber Tubes					1326							
11		Nozzle Bands					370							
12		Nozzle Tubes					1054							
13		Gimbal Assembly					(1676)							
14		Gimbal Support Structure					(1400)							
15		Electrical (J-Box)					(20)							
16		Integration Hardware					(380)							
17		Engine Weight - Dry					(11467)							
18		Residual Fuel					(3152)							
19		Residual Oxidizer					(337)							
20		Engine Weight - Wet					(14956)				100			

ALTERNATE - 1200 K REGENERATIVE CHAMBER WITH ABLATIVE TECHROLL® NOZZLE - GIMBALED

MODEL Swivel Nozzle
CONFIGURATION 1200K
REPORT NO.
SUBMITTAL DATE
REPORTING PERIOD

LINE	STAGE	①	ORIG. SPEC. WEIGHT PER ②	APPR'D. SPEC. CHANGES ③	REV'D. SPEC. WEIGHT AS OF ② + ③ ④	OVER OR UNDER WEIGHT ⑤	CURRENT STATUS ④ + ⑤ ⑦+⑧+⑨ ⑥	LAST STATUS REPORT DATED ⑦	CHANGES: LAST TO CURRENT STATUS GFE CHANGES ⑧	CHANGES: LAST TO CURRENT STATUS CONTRACTOR CHANGES ⑨	BASIS FOR CURRENT DATA % EST. ⑩	BASIS FOR CURRENT DATA % CALC. ⑪	BASIS FOR CURRENT DATA % ACTUAL ⑫	NOTES ⑬
1		Valves					(980)				100			
2		Oxidizer					535							
3		Fuel					445							
4		Injector					(660)							
5		Fuel Manifold & Duct					(421)							
6		Chamber Assembly					(4842)							
7		Head & Shell					755							
8		Head Tubes					411							
9		Comb. Chamber Shell					1759							
10		Comb. Chamber Tubes					1326							
11		Nozzle Bands & Tubes					591							
12		Ablative Nozzle					(3636)							
13		Fixed Engine Support Structure					(800)							
14		Nozzle Seal					(240)							
15		Electrical (J-Box)					(20)							
16		Integration Hardware					(380)							
17		Engine Wt. - Dry					(11979)							
18		Residual Fuel					(1952)							
19		Residual Oxygen					(337)							
20		Engine Wt. - Wet					(14268)							
21		Actuator (4)					(300)							
22		APU Servo Valves					(162)							
23		Engine Wt. - Wet					(14730)				100			

ALTERNATE - 1200K REGENERATING CHAMBER WITH LITVC

MODEL LITVC Regenerative Engine
CONFIGURATION 1200 K
REPORT NO.
SUBMITTAL DATE
REPORTING PERIOD

LINE	STAGE	①	ORIG. SPEC. WEIGHT PER ②	APPR'D. SPEC. CHANGES ③	REV'D. SPEC. WEIGHT AS OF ② + ③ ④	OVER OR UNDER WEIGHT ⑤	CURRENT STATUS ④ + ⑤ ⑦+⑧+⑨ ⑥	LAST STATUS REPORT DATED ⑦	CHANGES: LAST TO CURRENT STATUS GFE CHANGES ⑧	CHANGES: LAST TO CURRENT STATUS CONTRACTOR CHANGES ⑨	BASIS FOR CURRENT DATA % EST. ⑩	BASIS FOR CURRENT DATA % CALC. ⑪	BASIS FOR CURRENT DATA % ACTUAL ⑫	NOTES ⑬
1		Valves					(980)				100			
2		Oxidizer					535							
3		Fuel					445							
4		Injector					(660)							
5		Fuel Manifold & Duct					(676)							
6		Chamber Assembly					(6375)							
7		Head End Shell					755							
8		Head Tubes					411							
9		Combustion Chamber Shell					1759							
10		Combustion Chamber Tubes					1326							
11		Nozzle Bands					1070							
12		Nozzle Tubes					1054							
13		Engine Support Structure					(800)							
14		LITVC Ducts & Valves					(1670)							
15		Electrical (J-Box)					(20)							
16		Integration Hardware					(380)							
17		Engine Weight - Dry					(11561)							
18		Residual Fuel					(2859)							
19		Residual Oxidizer					(1755)							
20		Engine Weight - Wet					(16175)				100			

ALTERNATE - 1200K DUCT COOLED CHAMBER - GIMBALED

MODEL Duct Cooled Engine
CONFIGURATION 1200 K Gimbaled
REPORT NO.
SUBMITTAL DATE
REPORTING PERIOD

LINE	STAGE	①	ORIG. SPEC. WEIGHT PER ②	APPR'D. SPEC. CHANGES ③	REV'D. SPEC. WEIGHT AS OF ② + ③ ④	OVER OR UNDER WEIGHT ⑤	CURRENT STATUS ④ + ⑤ ⑦+⑧+⑨ ⑥	LAST STATUS REPORT DATED ⑦	CHANGES: LAST TO CURRENT STATUS GFE CHANGES ⑧	CHANGES: LAST TO CURRENT STATUS CONTRACTOR CHANGES ⑨	BASIS FOR CURRENT DATA % EST. ⑩	BASIS FOR CURRENT DATA % CALC. ⑪	BASIS FOR CURRENT DATA % ACTUAL ⑫	NOTES ⑬
1		Valves					(980)				100			
2		Oxidizer					535							
3		Fuel					445							
4		Injector					(660)							
5		Fuel Manifold & Inlet					(160)							
6		Combustion Chamber & Assy.					(5847)							
7		Combustion Chamber Shell					3710							
8		Combustion Chamber Duct					1567							
9		Nozzle Stiffening Flange					570							
10		Gimbal Assembly					(1676)							
11		Gimbal Support Structure					(1400)							
12		Electrical (J-Box)					(20)							
13		Integration Hardware					(380)							
14		Engine Weight - Dry					(11123)							
15		Residual Fuel					(410)							
16		Residual Oxidizer					(337)							
17		Engine Weight - Wet					(11870)				100			

JUSTIFICATION OF CHANGES SINCE LAST REPORT

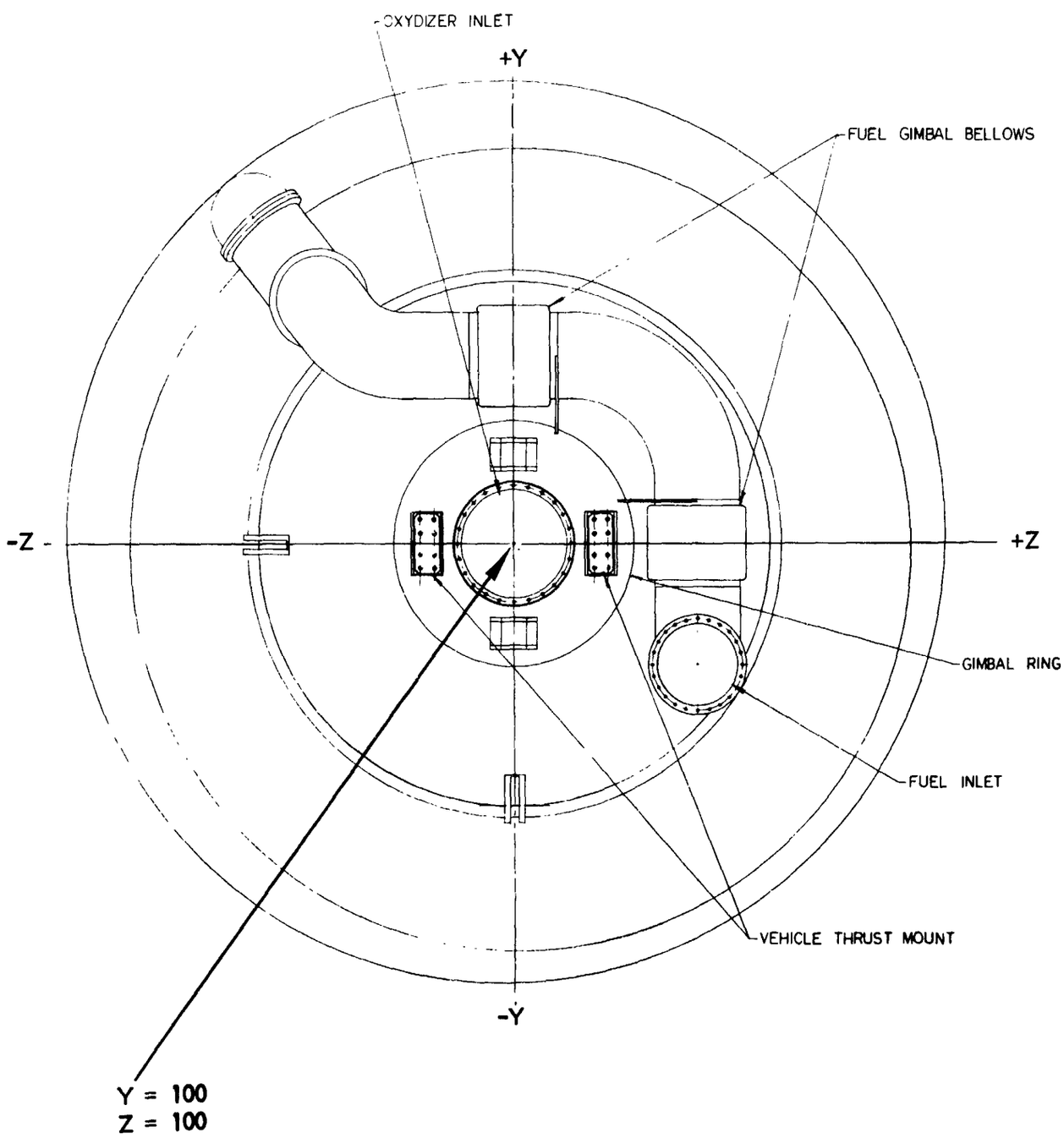
MODEL REGENERATIVE ENGINE
CONFIGURATION 1200K - GIMBALED
REPORT NO.
SUBMITTAL DATE
REPORTING PERIOD

LINE	STAGE	(1)	G.F.E. CHANGES (2)	CONTRACTOR CHANGES (3)	EXPLANATION (4)	WEIGHT STATUS PAGE	WEIGHT STATUS LINE
			NOT APPLICABLE				

IMPROVEMENT POTENTIAL		
PROBLEM	**ACTION BEING TAKEN TO ALLEVIATE PROBLEM**	**BEST EST. OF WT. EFFECT**
NOT APPLICABLE		

FOLDOUT FRAME

1200 K REC
MA



BEL

OX

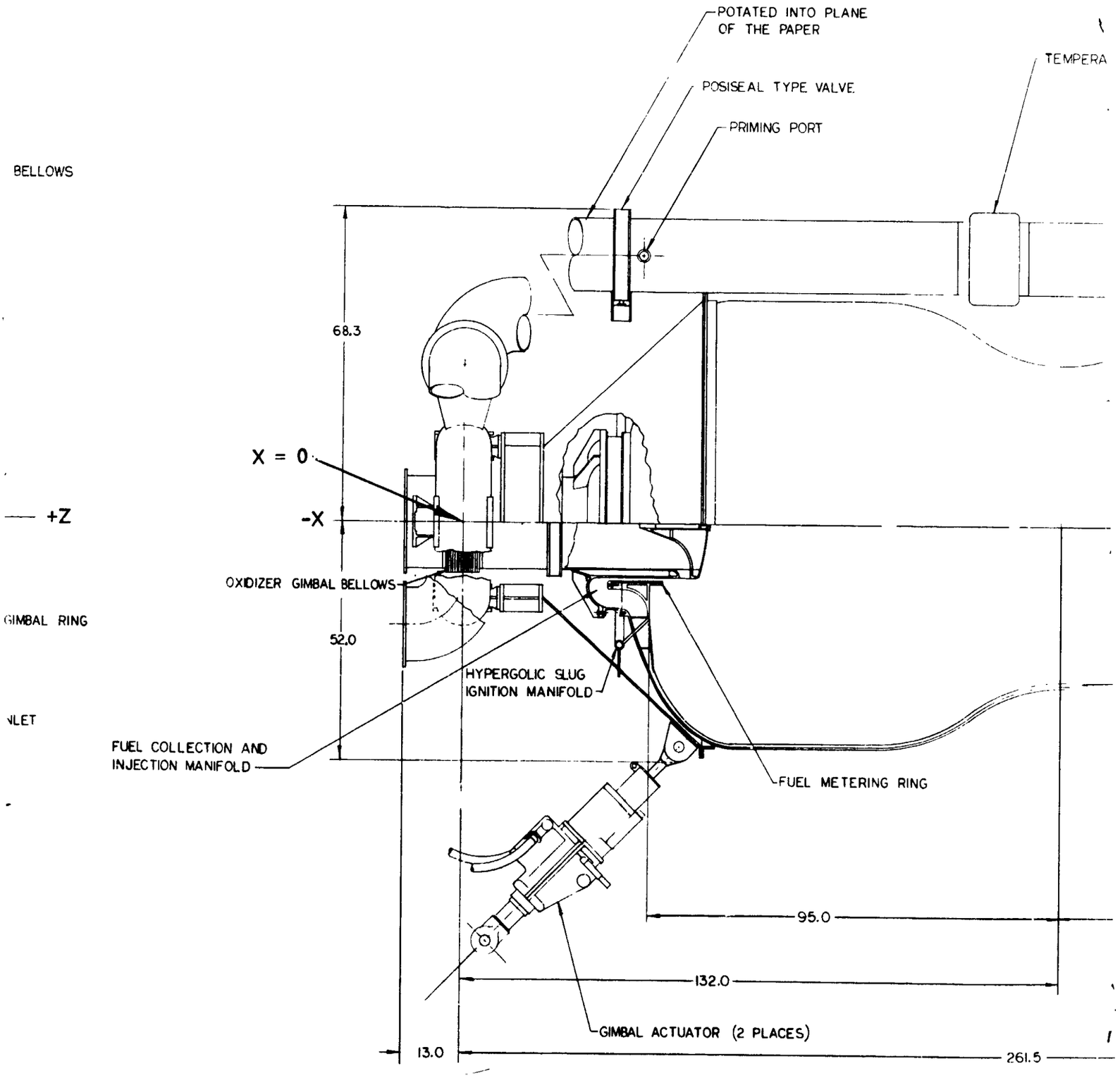
GIM

NLET

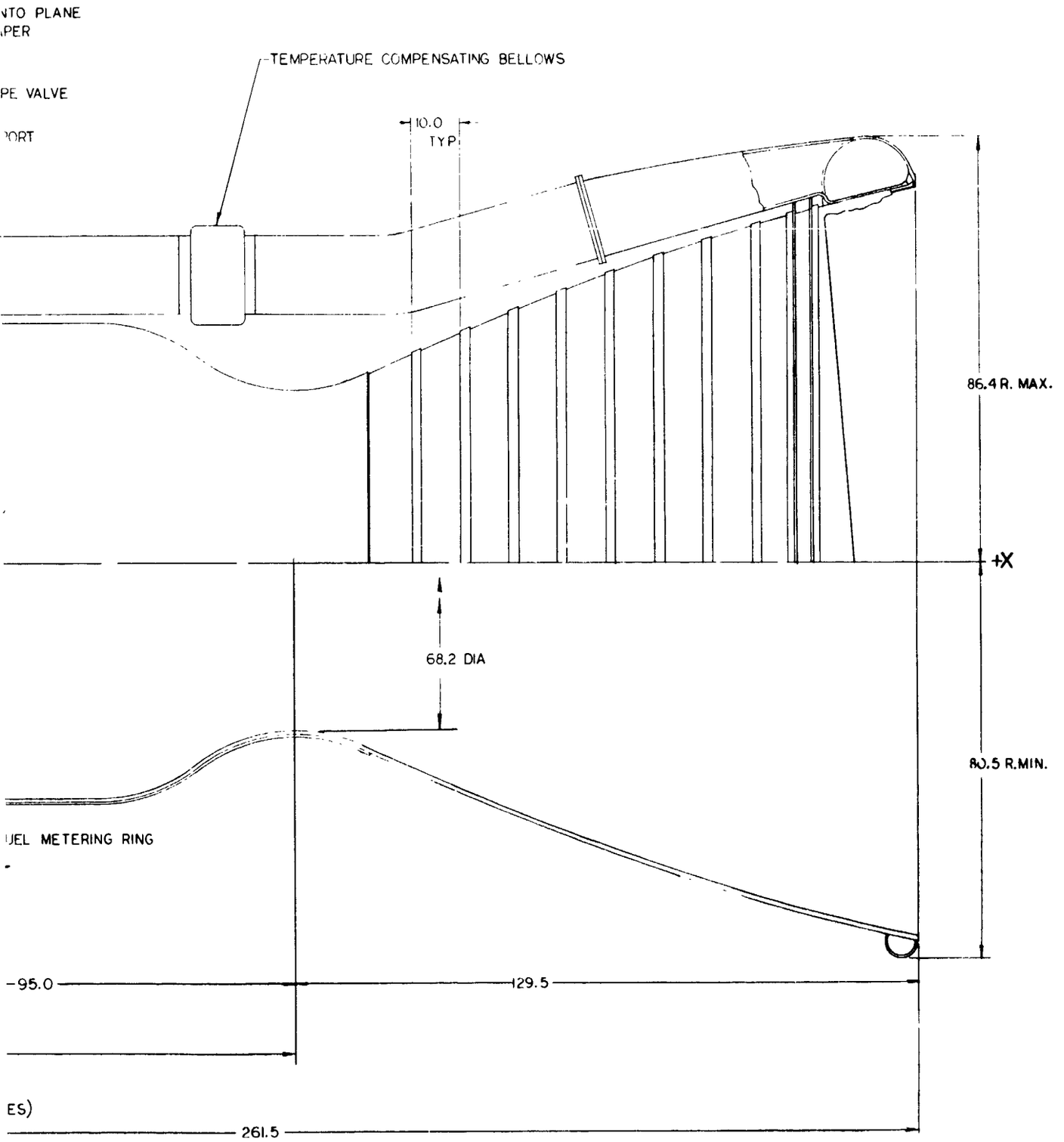
FUEL COLLECTION A
INJECTION MANIFOLD

FOLDOUT FRAME 2

1200 K REGENERATIVE ENGINE - GIMBALED, ε = 5
MASS PROPERTIES AXIS SYSTEM



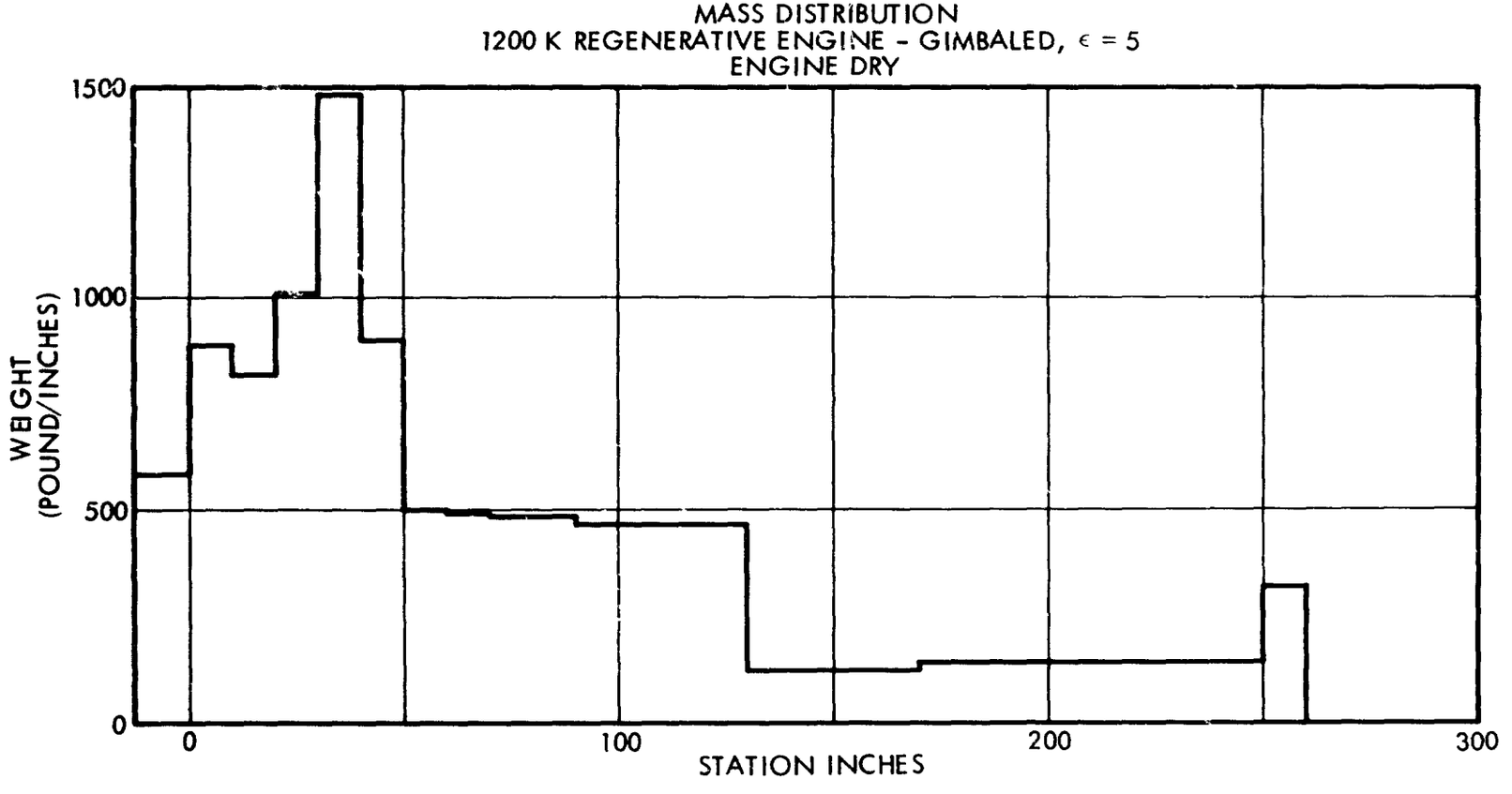
FOLDOUT FRAME 3



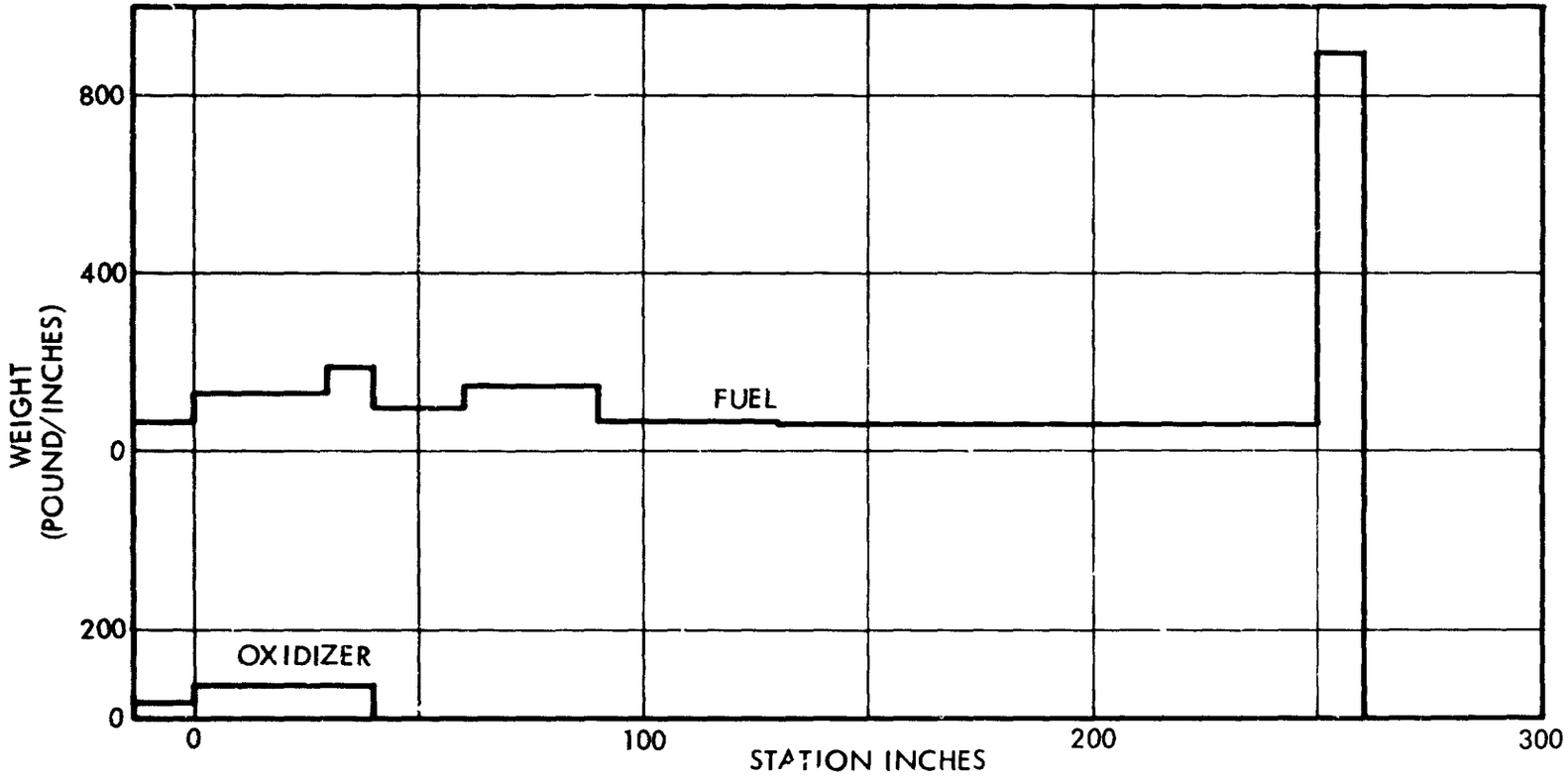
MASS PROPERTIES SUBSTANTIATING DATA

The reported weight and centers of gravity data for the engine are estimated.

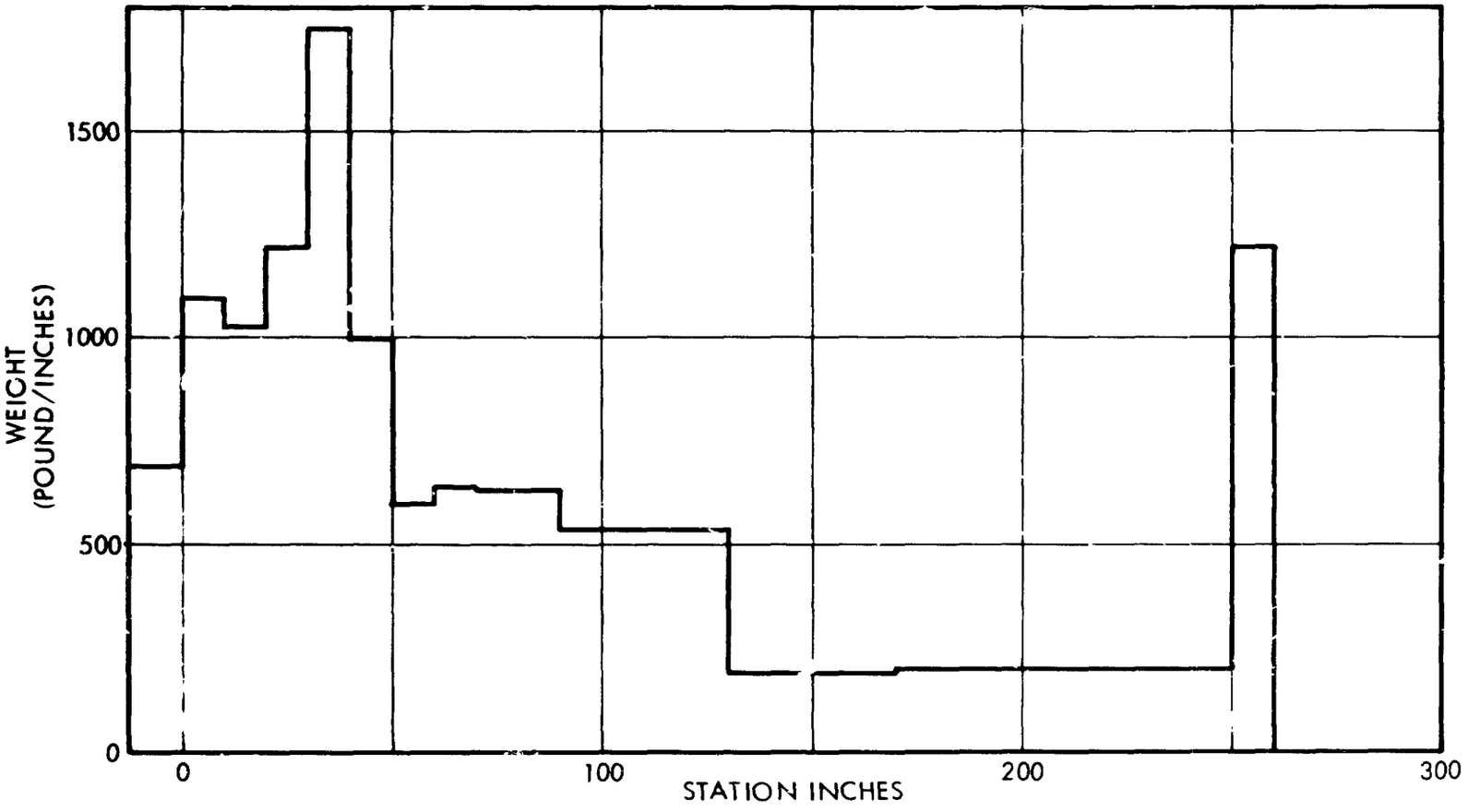
The Olivetti-Underwood Programma 101 and the On-Line Computer are used to compile total center of gravity and moments of inertia.


MASS DISTRIBUTION
1200 K REGENERATIVE ENGINE - GIMBALED, ϵ = 5
ENGINE DRY
WEIGHT (POUND/INCHES)
1500
1000
500
0
0
100
200
300
STATION INCHES

MASS DISTRIBUTION
1200 K REGENERATIVE ENGINE-GIMBALED, $\epsilon = 5$
FUEL AND OXIDIZER ONLY



MASS DISTRIBUTION
1200 K REGENERATIVE ENGINE-GIMBALED, $\epsilon = 5$
ENGINE PLUS FUEL AND OXIDIZER



CRITICAL MASS PROPERTIES UNCERTAINTIES

The following uncertainty values have been assigned to the mass properties of system components:

Actual	± 1%
Calculated	± 5%
Estimated	±10%

These values will be used in the integration of system components into the complete system mass properties program. The program will then reflect the critical mass properties dispersions for the complete system.

The values of 1%, 5% and 10% for actual, calculated and estimated mass properties have been used with very satisfactory results in other hardware programs such as LMDE, RMIP, etc.

Actual mass properties are those which have been experimentally determined by the use of scales, c.g. devices, etc. Calculated mass properties are analytically derived from released drawings and, where applicable, mass properties appearing in the vendor's catalogue may be considered as calculated mass properties. Estimated mass properties are analytically derived from layouts or sketches, and may also include vendor-derived values experimentally obtained from a prototype component.

CAPACITY AND LOADING INFORMATION FOR FLUIDS AND PROPELLANTS

TRAPPED PROPELLANT

	WT. LBS.	$\bar{X}$ IN.	$\bar{Y}$ IN.	$\bar{Z}$ IN.	Ix SL-FT^2	Iy SL-FT^2	Iz SL-FT^2
Fuel	3152	141.90	123.02	85.11	2480	7564	7584
Oxidizer	337	20.50	100.00	100.00	4	30	30

SEQUENTIAL MASS PROPERTIES

NOT APPLICABLE

POWERED FLIGHT MASS PROPERTIES

NOT APPLICABLE

GOVERNMENT FURNISHED EQUIPMENT

NOT APPLICABLE

DESIGN DATA FOR MASS PROPERTIES ANALYSIS

NOT APPLICABLE

MASS PROPERTIES LIMITS

NOT APPLICABLE

PARAMETERS AND INVENTORY OF FLUID AND PROPULSION

NOT APPLICABLE

MASS PROPERTIES HISTORICAL LOG

NOT APPLICABLE

TRADE STUDY DATA

NOT APPLICABLE

ABBREVIATIONS

WT.:	Weight
LBS.:	Pounds
$\overline{X}$:	Center of Gravity - X Axis
$\overline{Y}$:	Center of Gravity - Y Axis
$\overline{Z}$:	Center of Gravity - Z Axis
M.I.:	Moment of Inertia
Ix:	Moment of Inertia - About X Axis
Iy:	Moment of Inertia - About Y Axis
Iz:	Moment of Inertia - About Z Axis